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ABOUT THIS ISSUE

The analyst who bears the heavy responsibility of investing and reinvesting other people's funds makes a detailed study of company operations and prospects for the future. Indispensable to his examination is the detailed study of the research and development work, both in its long and short-term aspects, of the company under consideration. Our first article, entitled "The Investment Analyst's Evaluation of Industrial Research Capabilities," is a fascinating account of the guidelines employed by a forward-looking executive who has achieved success in the investment field. The author, Ora C. Roehl, is Vice President of Keystone Custodian Funds of Boston, Massachusetts.

The quality of written reports is one criterion for estimation of the caliber of an organization. Internal reports are judged by employees and managers; papers in journals make their impression on all who read them. But carefully prepared documents exert an influence of even greater depth. They can actually increase the effectiveness of organizational planning and research. They greatly reduce the sheer bulk of scientific output with increase in clarity and no loss of information imparted. Our second article, by Robert F. Marschner and J. O. Howe, tells how such improvements are accomplished at the Standard Oil Company (Indiana).

The fall 1959 meeting of the Industrial Research Institute had a session devoted to the effects of international product competition on United States research. Speakers discussed the topic in its various aspects, and in particular, formal presentations were made by representatives of the optical, chemical, electrical, and steel industries. Mr. P. M. Arnold, Manager, Research and De-

velopment Department, Phillips Petroleum Company was chairman of the session. The speakers were H. S. Coleman, Vice President in Charge of Research and Engineering, Bausch & Lomb Optical Company; L. C. Chamberlain, Jr., Assistant to the Director of Research, The Dow Chemical Company; D. G. Wilson, Assistant Vice President, Stromberg-Carlson Division of General Dynamics Corporation; and T. F. Oldt, Vice President-Research, Armco Steel Corporation. The substance of their talks was combined into one paper which is presented as our third article.

With this issue, we conclude the report by Dr. James A. Bralley of the study group meetings on the Environment for Creativity. The first half of his report was presented in the preceding issue of *Research Management,* **3**, No. 2, 97 (1960).

THE INVESTMENT ANALYST'S EVALUATION OF INDUSTRIAL RESEARCH CAPABILITIES

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The securities markets continue to give great weight to the research and development factor in evaluating the securities of industrial companies. If a company is not technically sound, then its future is not sound. Such a company is not a good investment, and this fact is reflected sooner or later in the price action of the company's securities.

The securities markets of the free world do not always give prompt and thoroughly reasoned evaluations, but they do offer an objective test of management, and, in the long run, the decisions of the market place have a way of being correct. While the securities markets provide a good long-term index of the efficiency of corporate management, it is the objective of every financial analyst to expedite the appraising process and to anticipate the "dictums of the stock market." Proper evaluation can make an invested dollar multiply by ten or twenty whereas a poorly invested dollar can be lost. So the investment analyst is paying more and more attention, not only to technological or scientific research and development, but to industrial innovations of all kinds.

As is usually the case with questions such as the one we are considering, it is impossible to arrange the factors to be reviewed

in assembly line fashion and then come out at the end with a completely satisfactory answer. But we can make observations. The professional investor attempts to evaluate the quality of industrial research and development, first by developing a broad perspective. The investment world's understanding of the importance of this aspect is discussed first. Next, the analyst orients himself to the more specific problems that face the industry of which the company being evaluated is a part. Finally he examines the company itself. The analyst knows that the only way he can get at the heart of any corporate problem is to appraise the quality of the management that is responsible for coming up with the right answers. The analyst will have accumulated certain conclusions over the years as to what he thinks are evidences of good and poor management. We will list some of these that apply to top management and to research management, and a few general conclusions that seem pertinent today will also be drawn.

Research Perspective

Industrial research has definitely grown up. No longer is it necessary to sell the need for research in industry. The mystery and magic formerly associated with the words "industrial research" have disappeared. The fact that considerable money is being spent for research is taken for granted. The question the investment analyst is asking company management today is not, "How much are you spending for research and development?" but rather, "What results has your research produced, and are these the results you expected?"

Research evaluation in 1960, therefore, is different from what it was even five years ago. It is more sophisticated. Research today is considered by most investment analysts as much a corporate function as are sales, production, and finance. This coming of age, this attainment of maturity on the part of research, brings with it many new questions, and, of course, a goodly number of the old problems are also still around.

Research Is Big Business

The National Science Foundation data indicate that expenditures for research and development to be undertaken in 1960 by various agencies are as given in Table I.

TABLE I

	Expenditures, $ millions
Federal government agencies	1,780
Industry	9,400
Colleges and universities	1,000
Other nonprofit organizations	250
Total	12,430

For 1970, some estimates run as high as $30 billion. About half of this research will be supported by the Federal Government, and about two-thirds of this will be spent on the physical sciences. Government expenditures for research are also an important economic factor, as many areas of the country and many companies are dependent on such research appropriations for their very livelihood. For many companies the continuance of Government support is the vital factor—and this fact is most important in any investment appraisal of such a company.

The magnitude of the amount spent for research is hard to visualize, but it is greater than the market value of the common stock of all but six of the twenty-five industries listed on the New York Stock Exchange. Research expenditures are twice as large as the value placed on the paper industry and about the same as the market evaluation of the entire steel and iron industries. Of the sales gain of the next few years, almost half is expected to come from new products of research. New plant expansion expenditures, on which the health of our economy so greatly depends, stem largely from research developments.

Thus, research is a basic national resource. It is an economic force, almost a needed raw material. Not only are individual companies dependent on research for their future business health, but our whole economy is dependent on research for growth and even for survival.

Research dollars may currently be looked at critically, but not any more so and maybe less critically, if the company's research programs are soundly conceived, than are the dollars being spent on other corporate activities. This is quite a fundamental change in investment attitude. Research is now a part of the company, and it is up to the corporation to see that money spent on research is not wasted, but rather is put to use for the benefit of the company. Research is now a strategic force in a company's struggle.

Research Is More Competitive

Research, however, has become very competitive, and it is increasingly difficult to make the research dollar pay its way. Competitive research often makes new products competitive before the production plants are even completed. Research is self-generating in a way: it feeds on itself and it has a tendency to spiral as new knowledge and new innovations beget other innovations. Dr. Killian recently said, "Scientific knowlege is doubling about every nine years; technological effort is doubling about every ten years; more advances have been made in science in the past fifty years than in all preceding history; and ninety per cent of the scientists who ever lived are probably alive today—an indication of the vast increase in scientific knowledge which lies ahead."

New developments are less the sole property of individual companies. A company in a research-based industry just has to be in the research forefront, even though research profits are sometimes harder to make, or be content to take an uncomfortable back seat position. This fact is extremely important to the investor, who can hardly afford to have his hard-earned savings invested in

a company that is lagging behind. The following two sentences, taken from actual recent recommendations for elimination of two securities from the portfolios of our funds, are indicative of the attitudes of investment analysts who must see to it that money entrusted to their care is wisely invested:

> "Recent research and development expenditures appear to have failed, for the first time in some years, to produce any new products which could be expected to sustain the upward trend of sales and earnings."
>
> "The company's record to date has been good, but there is disturbing evidence it has not kept up with the rapid advances in missile and electronic technology. We concluded that the holding represented a greater risk than it was desirable to assume."

Research Only One Factor in Corporate Health

While research and development are becoming more competitive and costly, this is not the only factor that concerns corporate management and the investor. For example, the cost of marketing the old and the new products of industry is also growing. It is interesting to note that spending for advertising has about doubled since 1950 and totalled $11.1 billion in 1959, just about the same as the amount spent on technological research. It does not make any sense to spend a lot of money on development if the company does not have the financial strength and ability to produce and market the results of research. Unless research is well conceived it can become a serious financial drain.

The investment analyst, therefore, looks upon technological research as only one part of the corporate whole. It is just as necessary that a company be strong in marketing, in manufacturing, in servicing, and in financial planning. Innovations in other areas can be just as meaningful to the company and the nation's economy as are technological developments.

Mr. Peter Drucker at MIT's Industrial Management Convocation last spring said, "Believe me, installment buying was as much of an innovation as anything the electronics industry has

produced, in its impact on the lives of people and the structure of the economy." Today innovations in marketing, in production planning, in value engineering, in inventory control, in making each department profit conscious, are all part of a company's creative activity . Management must make decisions on the use of corporate funds to be allocated for broad innovation—should the funds be used for technological and new product research, for marketing research, for economic analyses, or for operations research?

It must be noted that, while we still are being told that the nation's research effort is lagging, yet other voices are also being heard saying that the dollars spent for research could be used better elsewhere and that much research effort is really wasted. At the 1960 International Management Conference recently held in Australia one of the speakers, Dr. Kapferer of Germany, said, "We spend relatively too much money on technical research, and not enough on forecasting economic developments." He meant that more effort should be devoted to studies aimed at leveling off the peaks and valleys of the business cycle that continually plague the economies of the free world. Certain top research managers have also questioned research efforts saying, "There is a great tendency in much of the research of today to become a system and to become perfunctory rather than a great dynamic tool for growth. Many skilled scientists and engineers are working on poorly planned projects and much of the work, if successfully completed, will not be used." Statements like these cause the investment analyst to think twice before he becomes excited about the statements made by a company on the size of its research expenditures and its claims of how they are going to increase the company's profits in the years ahead.

These, then, are a few of the general considerations that help the investment analyst gain general perspective. These are factors that he has in the back of his mind when he begins to appraise the quality of a company's research effort.

Economic, Industrial and Company Orientation

Before anyone can make an evaluation of the technical competence of a company he must have an understanding of the economic and industrial atmosphere in which the company operates, and he must look at the record of what the company has been able to accomplish.

The Economic Background

The analyst must have an understanding of the general political situation, both domestic and foreign, along with some definite conclusions as to the business and economic problems that face the general economy and, more particularly, the industry and company in question. A company may have developed important new and improved production processes through its research, but if the economic climate is not favorable it may not be able to capitalize fully on such developments.

Now that the post-war, world-wide shortages have been largely overcome, world competition is going to be much keener; this fact is also of importance in evaluating the commercial success of new products and processes.

The point is that economic forces must be examined too before research on technology can proceed with confidence.

The Industry Background

The analyst must also have a basic understanding of the industry or industries in which the company operates. He will not only classify the companies by their major products, but also by the customers served. A company with most of its business dependent on the highly competitive consumer durable goods field will be entirely different from a company serving the electric light and power industry. A company serving the Army, Navy, and Air Force will be different from a company serving the oil industry.

A company building airplanes and engines has a different outlook from one serving the growing guided-missile field. Companies developing industrial controls will have different economic and profit-making problems from the companies producing electronic office equipment. Companies using automated machine tools may gain more profit than the machine tool company that developed the equipment.

Some of these fields will be basically more attractive as investment media than others, and the company with the greatest engineering know-how from the development, service, and selling points of view in the most attractive field will be the best investment. The objective is to try to determine the areas that hold the most profit potential and avoid investments in the areas that are overcrowded and highly competitive or where the business may be in a declining phase.

Research can be revolutionary, and whole industries can become obsolete in a short time. Unless the investor is aware of what is going on he may wake up some day to find that his investments have deteriorated while he was confidently sleeping.

Company Background

After the analyst has determined the broad economic and business background of the industry as a whole, he will next look into the company's own operations.

The analyst will check the achievements of the past and the current trends of the company's business. Detailed analyses are made of operating income and expenses for all phases of the company's operations to determine the trend of profit margins and to check the sales trends of the company's old and new products so as to obtain a picture of the soundness of the growth pattern. Sometimes a company gains a reputation for research competence by the fortuitous development of one or two products, and the analyst must determine if the products are still in the growth phase and

also if there is any chance that the company's research can again turn in comparable results.

The amount of money spent for engineering and research is broken down, if data are available, by areas of research and by types of engineering. Efforts are made to determine the money spent for basic research, for product improvement and for the creation of new products. These data are then compared to similar data for other companies and for the industry as a whole. This information is obtained from company managements, trade and engineering publications, government reports, and special studies that may be prepared by competent independent research and engineering firms.

Having done what work he can do on his own, the analyst also discusses the research activities of the specific company with the company's management, with the company's competitors and customers, and with consultants and specialists in the particular field. The analyst's visits with management are naturally most important and helpful. While he will have some general ideas as to the company's research work, generally only after a visit with management will he have enough information to enable him to make an investment decision. Here are a few factors he considers in evaluating top management and research management.

Research and Top Management

The analyst attempts to learn what it is that makes some managements excellent and others poor. Over a period of years he gains experience in doing this and he weaves in his acquired personal knowledge with the experience that his organization has gained over many years of management evaluation. Appraisal is a difficult task and can hardly ever be completely satisfactory—but it must be done.

Research expenditures and results can be discussed and analyzed, but behind all the research effort must be a motivating

force. This motivating force in the industrial establishments can only be top management. If the investor can have the best management in the business working for him, his problems are two-thirds solved. Thus, the investment analyst is always seeking some way to appraise both top management and research management.

Justice Holmes once said, "The art of life, not the philosophy, consists of making correct guesses on insufficient information; insufficient because we can never know all the elements that enter into a right decision." So it is with the problems the investor faces in trying to evaluate management. There will never be sufficient data to insure the correct decision. However, the best method in our business is to find or develop the prepared mind that out of experience and knowledge can instinctively or intuitively come up with the right answer.

If you ask the analyst what makes for top management he can only generalize along these lines: The successful top corporate management can be distinguished by the fact that it gives something of itself to the key corporate functions of finance, sales, purchasing, production, and engineering and research. Management must understand the financial mind, the sales mind, the production mind, and it must also understand and be sympathetic with the creative mind. At the same time management itself must stay young in thoughts, courageous in action, and imaginative enough so as not always to say no. Management must have a sound understanding of where the corporation is to go, how it plans to get there, and where the various corporate functions, including research and development, fit into the whole picture.

So much for the general approach to management. Let us become somewhat more specific.

Ten Top Management Question Areas

If management really believes that research is a major corporate function it must give sufficient time and effort to research

organization, to future plans, and to programs for research evaluation and measurement. It should be able to give the right answers to questions in the following areas.

1. What about the board of directors? Is it research oriented? A company's board is still responsible to the shareholders for the proper functioning of a company, even though too many boards unfortunately do not take their responsibilities as seriously as they should. Most boards have a periodic report on research submitted to them, but would it not be better (at least in research-based companies) if some one who actually knew something about research were always on the board and could speak for research and explain its significance. If it is policy to have at least a partially internal board, then surely the research head should be represented.

2. Does top management indicate its will that something is to be done about research, and its appreciation of the importance of the research function by giving research appropriate status in the company's organization chart? Does the engineering head or the research head (and there seems to be some trend again towards combining these functions under a single direction) have an appropriate title and is his position recognized? Where does the head of engineering fit into the company's executive salary scale? The salary scale often indicates the relative valuation management gives to various corporate endeavors.

3. Has management provided for an organization device to coordinate and obtain support for engineering and research, and to give them the benefit of the advice and counsel of other departments of the company? Do the president, the vice president for sales, the vice president for production and the other key officials apportion a liberal portion of their time to the company's engineering and research problems? Does the company president appreciate the significance of a technical problem even though he may not fully understand it? Is there a product development committee made up of the key divisions, which is responsible for new products

and product modification, or is there some other procedure whereby the entire top management is made cognizant of and appreciates the problems that affect the future of the company? This would include research related problems as well as other corporate functional problems. Are the duties of the central laboratory, how it is to work with the divisions, and the research responsibilities of the various divisions clearly defined? One of the major problems in every organization is the removal of friction and unhealthy competition that always exists between departments. Research is not going to flourish nor are the other major corporate functions going to proceed effectively unless management provides the proper communication channels. So the investment analyst always likes to know what they are.

4. Is management so busy and concerned with problems of the moment that it cannot pay enough attention to the future? The necessity for a written plan is so evident that it seems unnecessary even to mention it. However, it was just a few weeks ago that I talked with the vice president of a large company about this and his answer was, "Well that talk about a written plan is perhaps good, but in this organization I am the only one who could do it and I do not have the time." However, in the investment analyst's book, before any research program important enough to be considered a major corporate function can be undertaken, management must have a written statement of its research policies—what it is going to attempt and what it is not going to attempt to do.

5. Is there a continuous process of looking ahead five to ten years? By such future planning inertia is to some extent overcome and the corporation will adapt itself more readily to change than if there had been no forward planning. A company cannot change direction overnight. Management should have a definite idea of where its business stands today—where it is headed, and to what areas its scientific, research, and engineering activities are to be limited. Management should know whether the areas its research covers are in highly competitive fields or in fields where competi-

tion may not be quite so potent and more in line with the company's overall capabilities. Efforts must be made to determine the areas that hold the most profit potential and avoid those that are overcrowded and highly competitive or where the business may be in a declining phase.

6. Does management also know what profits could be expected from the money spent on specific engineering and research projects? Competent management would know what its engineering problems are today and what they might be in the future; it would have some idea as to what plans should be made now and what engineering and research funds should be committed to meet the future. It would be able to talk about the new products and product improvements required in, say, the next five- or ten-year period —and also the programs being developed to satisfy these requirements. It would have definite ideas as to the product life of its old and new products. It would know its problems, as the things that are wrong may be more important than the things that are right because the things that are right usually take care of themselves. Recognizing problems early enough to do something about them is a most important management function. But at the same time, it is not wise to have management and research spend time on problems that exist only because a product is on its way out.

7. Is management well informed on plans for translating successful research into successful commercial practice by financing and marketing the products? Definite ideas on how a new product is to be produced, sold, engineered, and serviced and what it would cost should be kept in mind. It is of no use to do research if the financial resources to market the results of research are lacking.

8. Are research plans expressed in dollars and cents through yearly and longer-term budgets? Policies as to the amount of a company's profits that should be ploughed back into research need to be determined. This will largely depend, of course, on the amount of money available and on the chances for success in the research program. The amount of money spent for research

should be broken down by areas of research and by types of engineering. The portions to be spent on basic research, on creation of new products, and for product and process improvement (and also on other nontechnological research efforts peculiar to the company) should also be indicated, thus giving body to broad research plans. These broad plans should cover more than a year, for we have known of companies where a few hundred thousand dollars were budgeted for a research project which actually ran into millions of dollars before any results were obtained. Annual budgets should be footnoted so that total ultimate cost extending over the period of needed exploration is also known and can be weighed.

9. The corporate enterprises that we are talking about exist for the purpose of making money—and money is spent on the research function to earn money. It is necessary, therefore, for management to measure the results of the corporation's research work. There are cash yardsticks such as weighing research costs against savings effected through improved processes, or against increased profits, or by giving research credit for an appropriate portion of the profit made on new products. A fruitful field for evaluation of research is the company's capital expenditure budget. Here a picture of the company's growth pattern can be obtained. What per cent, for example, of the budget is for the production of new products? What per cent for older products? What profit margins are expected from the new products to be produced by the new plants? What per cent must be spent or is being spent to make or keep the company competitive with others in its business? How do engineering and development expenditures of the past correlate with capital expenditures of today (and with today's sales and profits) ? All of these checks give some hint as to the quality and the status of a company's engineering, research, and development work. If most of the money is being spent to catch up with competition in a low-profit field rather than on being a leader in a new high-profit field, it does not speak too well for the quality of the company's management.

10. Management should know what business it has lost by not being the leader in its field. It is important to know if an engineering project resulted in a profit or a loss, but it is just as important to know the cost of lost opportunity, and this phase of research evaluation is too often entirely neglected. Management should also know the sources of its new products—did they develop from work done originally by its competitors, from university research, from government research, from foreign sources, or from its own research staff? How many patents were issued to the company in its chosen fields as compared to its competitors? How many new products or product improvements did the company introduce compared to its competitors?

Research Management

Research is a business and it must be run as a business. Research management must not only understand research, but it must also understand business management functions. The head of a corporate function must be a corporate man. The vice president in charge of engineering and research, in addition to understanding his own operation better than anyone else in the company, must have many of the qualities top management must have—he must be a financial man who appreciates the company's profit problems and runs his operations accordingly; he must understand the sales problems; he must work closely with production; be sympathetic with the comptroller; and then of course he is a scientist and an administrator. A mightly tough assignment and not one for "a tongue-tied specialist" but rather a job, as Sir George Nelson recently put it, for an "all-arounder."

Five Research Management Question Areas

The investment analyst has also developed question areas concerning research management on which he needs information for his appraisal.

1. Research management, just as top company management, needs a written goal. Are the research budgets, plans and programs all tied into the company's master plans—but at the same time more specific so that the department can accomplish its mission? This requires a fundamental understanding of what is going on in the business world and in research. Is a periodic report prepared on what is happening in the fundamental technical and research areas that affect the company? Does the report have suggestions as to future courses of action that the company should undertake? The research effort must be organized so that the corporation's research objectives can be met. Research effort that should be concerned with the company's future should not be expended for solving day-to-day production problems.

2. Scientific research on research is coming into its own. The investment analyst likes to know how progressive the research head of a company is in his thinking. Does he appear to have an understanding of the scientific and research process? What are his answers to questions such as these? How does a scientist discover? How does a research man comprehend new relationships and come up with an invention? How does an engineer design and evaluate? A methodology for creative and inventive work is being developed and one would think that the research department, of all company activities, would lead in accepting innovations in its field, but unfortunately the human trait which resists change is also present in many scientists and engineers. As the research function grows and is accepted, more and better ways to utilize research at the least cost will be found. It is up to the research head to be a leader in this field and to discover and use new methods of research organization and operation ahead of the company's competitors. In this connection it is interesting to note the emphasis in the recent Rockefeller Foundation Report on the fact that "progress in science frequently depends on the development of good methods."

3. The research manager must also do his own evaluating. Does the research head know what research costs are, and what

they are contributing to company profits? Are studies made of what is being accomplished by competitive research activities? The costs of arriving at an answer must be explored. The long-shot, low-cost chance must be weighed against perhaps the more costly, surer way. Research mania, which seems to spring up every once in a while, must be avoided. Studies must be made to be sure that the product improvement on which research proposes to work will have a long enough life to make the research profitable. Risks, however, must be taken or research will become routine and mediocre. It is oftentimes puzzling to the investment analyst why an older, established company with a big research department is so often outrun by a relatively small newcomer to the field. The answer that the research head of one such company gave is, "We leave the ivory tower stuff to the universities and big companies—our job is to concentrate on engineering and manufacturing so that we can sell the best product at the lowest cost." And they seem to be able to do it. This may be a somewhat opportunistic attitude, but it raises questions as to whether proper effort is being given in the larger companies to getting a good product out and profitably produced. The answer to all problems of this sort is competent men.

4. The investment analyst thus wants to know also something about the caliber of the men working in the research department. In this area the investment analyst likes to find companies undertaking studies as to just what work the individuals in the research department are doing in order to determine if a scientist or trained engineer is doing routine work that could be done just as well by some one else. Studies of yardsticks to measure a day's work, job satisfaction studies, and studies of the further use of data processing and high-speed calculating equipment as well as studies on the possibilities of utilizing outside research organizations and universities to a greater extent are also usually found on the work agenda of the well-regarded research managers.

5. A good general measure of research management compe-

tence for the investment analyst is the opinion that others have of a company's research activity. What is the reputation of the company's research organization in the outside world? Has the company been able to attract top-grade men? Is the turnover low? The opinions that competitors, independent research consultants, bankers, and investment people have about the quality of a company's research work is often very good indication of relative quality. The investment analyst likes to find a research head who can tell of the number of profitable firsts that the company has had, the contributions his men are making to technical societies, and who himself has developed a solid technical (not a public-relations-counsel inspired) reputation. Then if he is an accepted leader, with a voice that is listened to within the company, the analyst can proceed with confidence.

Conclusion

Business managers, in searching for ways and means to better solve management problems, have long been looking to the social sciences, but more recently data accumulated by the biological sciences are also being examined. Organisms continue to live only if they adapt and adjust themselves to change, and when a static period occurs, the organism ceases to exist. This appears to be the case also with business organizations, and so business managers may find that they also must have an understanding of ecology to properly fulfill their functions.

There may be some question about ecology giving us the answers, but there is no question about the need for an understanding of the importance of research and development by a company's management and by the investor who furnishes the funds. Years ago the investment analyst talked principally about price earnings ratios, consumer disposable income, gross national product, and margins before and after taxes. These factors are just as important as they ever were, but the analyst today is just as much con-

cerned with magneto-hydrodynamics, thermionics, and molectronics. The analyst of today and tomorrow has to have an appreciation of technological developments and, in fact, of innovations of all kinds if he is to properly serve his clients.

The business managers of the future will also need to be more innovation-acclimated as well as technically oriented. This poses problems not only in evaluating present management, but also in evaluating the training of managers for future service. Maybe the business management and engineering schools have a somewhat different job to do today in preparing men for business leadership. The successful manager of the future will need to have a greater appreciation of technology and he will need to be trained in the innovation process more than he has been.

The investor is concerned not only with the efficient operation of individual companies, but also with the nation's general business health. Investment in U.S. securities is not going to be sound if the industries cannot meet world-wide competition. Success in the competitive struggle will require continual allocation of substantial sums for technological research, and the investor hopes that similar effort will also be devoted to innovations in all corporate functions.

There is nothing more comforting to an investor than to know that a company in which he has invested his savings is a true leader in research and that its top management and its research management are in good hands.

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BETTER WRITTEN REPORTS*

ROBERT F. MARSCHNER
Assistant Director of Information and Communications
and
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Somewhat more than half the time that a scientist or engineer spends upon his profession goes for communication. Some of it consists of formal speech and informal conversation, but the bulk comprises written communication. After all, reading and writing are essential for ideas to traverse space and time. Reading in search of ideas consumes much time and people have come to accept the cost. But the writing of reports always seems to require an inordinate amount of time, because of the thinking that is required. As scientific knowledge and engineering technology grow and as the number of people involved increases, the need for written communication inevitably soars.

Today in industry, the scientist or engineer in research and development accomplishes much of his work with the aid of technicians, operators, clerks, and various other nonprofessional or semiprofessional assistants. But when it comes to writing up the job, he is usually pretty much on his own. Sometimes arbitrary

* Presented at Conference on Efficient Utilization of Scientists and Engineers, held in Chicago, Illinois, on December 1, 1959, under the auspices of the President's Committee on Scientists and Engineers.

rules of reporting are imposed that do more harm than good. The very task with which he rarely gets help is the one at which he is often least competent.

Schools have failed dismally to teach writing as a tool of communication. Composition is slighted in most high schools, and the classical freshman theme has almost disappeared from college. Precise exposition seems not to be taught at all. The first need for expressing original ideas in writing may not arise until the time comes to prepare a graduate thesis. The scientist or engineer then imitates the pompousness of textbooks and the vagueness of the professional journals, under the mistaken impression that such is the style expected of him. Now that education is front-page news, original writing may get more emphasis. But that cannot help the efficiency of practicing scientists and engineers today.

Presenting thoughts in words is necessarily complex, because the three successive operations involved require different attributes. First is the analytical task of defining the new thoughts and arranging them in logical sequence. Next comes the creative task of writing appropriate words upon paper. Last comes the critical task of smoothing and sharpening. Few scientists and engineers have all three abilities developed to a degree that enables them to write efficiently.

Assistance

Two approaches might be used to improve the written communications of an entire staff of scientists and engineers. One is to assign all writing tasks to people who, either by ability or by training, do a better-than-average job—a direct and costly approach that is often adopted when technical work is translated into instructions that must be understood by laymen. The other is to provide on-the-job training—an approach that seems preferable when most of the writing must be done at the professional level. Probably large organizations could profitably employ both approaches.

From the standpoint of efficient use of scientists and engineers, on-the-job training in writing has the greater long-run advantage. Never will professional people have any less to explain than they do now. Knowledge and method are their province; inability to explain is a weakness to be corrected, not a blemish to be covered. Setting the right words in the right sequence for the minds of others requires hard thinking. No amount of routine writing by others can replace it.

Unless the need for better written communication is recognized and endorsed by management, on-the-job training can not function well. Scientists and engineers are impatient to get on with their jobs, many believe that good writing is a marginal skill, and some resist the very idea that there is room for improvement. Management needs to emphasize that reporting is part of the job. It must sell the importance of good reports to the company, the man, and the profession, and it would do well to be sure of what it wants in written communication.

A good way to endorse better written reports is to provide talks to the staff on the subject. They might be given by a consultant, an astute university professor, or by one of the staff who has the necessary interest and experience. Particularly effective in illustrating such talks are examples—bad and good—taken from past writing efforts of those receiving instruction. Although fundamentals need to be stressed, the subject must be treated from the standpoint of the scientist and engineer, rather than that of the English teacher.

Because the effects soon wear off, talks to the staff are but a gambit. Reminders and follow-ups keep the subject alive. For example, our one-page memorandum called "Writing Matters" is distributed at frequent intervals. It includes analyses of critical writing problems, adaptations of key principles of writing to local needs, and summary articles on specific aspects of writing. A good follow-up is a program of conferences between individual members of the staff and writing experts. Analysis of the writing

of individuals usually reveals some characteristics that warrant greater use and others that should be avoided.

But occasional attention is not enough to insure high-quality reports. There is always something to be done: changing needs must be analyzed, new problems isolated, and cures designed and tried. Moreover, help is needed most while the scientist or engineer is writing a report. Only constant attention suffices, whether internal reports or outside publications are concerned.

Improving Internal Reports

Internal reports in most research and development organizations are of two distinct kinds: chronological and topical. Chronological reports are administrative documents prepared at some calendar interval, usually by the supervisor with the help of the men reporting to him. Typically, these reports repose in files, where they are arranged in order of date. Topical reports are technological documents, usually prepared by nonsupervisory men; they typically are found in the library, catalogued by subject. Despite the many obvious points of difference, chronological and topical reports are often confused, and trouble almost always results when they are.

Chronological reports differ from one organization to another. The pattern is often dictated—sometimes arbitrarily. Writing and reading habits—good or bad—of experienced supervisors are hard to change. Fortunately, once the local pattern is grasped, chronological reports almost write themselves.

Topical reports are—or should be—nearly alike everywhere. Upon them depends scientific and technological progress. They range from transient coverage of incomplete studies to permanent documents containing extensive data. It may be advisable to leave the writing of transient memoranda exclusively in the hands of individual professional men to provide experience and permit evaluation of their competence at the preparation of permanent

reports. The bigger job of writing permanent research and development reports, however, benefits far more from trained help than it suffers from loss of individuality.

Three sound principles for permanent reports are: keep the pattern simple, give those responsible for the work full credit, and provide help when it is needed. For several years we have provided the assistance of technically trained writing experts for authors who wished to make use of this service. Almost the only requirement is that the manuscript be typed before review.

The organization of a report proves to be the biggest weakness. It is a most serious one, for reorganization may call for extensive rewriting. The cure lies in outlining all the way down to the paragraph level, preferably by using the key thoughts or words of the successive topic sentences as the outline. Any conventional pattern—provided it is rational—will satisfy the needs of most readers and has the advantage that thoughts and data are readily inserted. The biggest job of the writing expert my be to convince the author that better arrangement can increase understandability, avoid repetition, and save space and reading time.

Inadequate orientation is a smaller but tougher problem than weak organization. Seldom is a subject as complicated as the report makes it. For clarification, the author must provide less-informed readers with enough steering words to guide them through the report, while not dwelling on the commonplace to the resentment of the better-informed. There can be no pattern to follow, for each report has its own needs. The best device is for the author to get help from a less-informed reader, preferably a technically trained writing expert. A dozen words in just the right places can convert an obscure report to a lucid one.

Once problems of organization and orientation are solved, other difficulties are not hard to find and overcome. Overqualification is a common fault. Use of so many words that simple meanings are hidden is bad. The tendency to provide too much detail and too little significance is familiar. Such conventional

shortcomings as ridiculous sentence structure, piled-up adjectives, ill-chosen words, and incorrect punctuation are "easy pickings" for a qualified writing expert.

Preparing Better Publications

Published articles represent a large fraction of writing effort in the sciences. Concepts and knowledge expressed by individual authors in professional journals are essential to the advancement of science. In engineering, on the other hand, success and satisfaction tend to be measured in structures, equipment, and products. But even in the applied fields, the quality of research and development effort tends to be judged from publications—or lack of them. Because of the permanent nature and broad readership of published documents, extraordinary attention to preparation is warranted.

Almost any management, before it allows proprietary information to benefit outsiders, requires some kind of review. Management must guard patentable ideas, and rightly wants to know what its scientists and engineers intend to publish. But seldom has management thought about the eventual value of the document to science and engineering, or the ability of authors to handle such valuable material. Ten years ago, our company took steps to improve its publication practices.

A publications committee is assigned the task of helping authors do a better job of communication with their professional counterparts elsewhere. Its five members include a permanent chairman and secretary plus three rotating members selected from supervisors in various areas of research and development. All manuscripts intended for publication must first undergo review. The committee learned early that, to be effective, it had to sit down with authors for as long as needed to resolve the questions and problems involved. Six-hour sessions are frequent with manuscripts only ten pages long, and some papers have to be reviewed again.

As might be expected, organization is the biggest problem in publications, as it is in internal reports. Even when the manuscript is derived from an earlier report, both organization and orientation may need attention, for the scope is almost invariably broader or narrower. An understandable fault is the tendency of authors to include inconsequential aspects of the work simply because such work was done, rather than because it contributed significantly to the solution of the problem. Out of this background have developed three guideposts that the committee often finds occasion to repeat:

1. Write for the reader
2. Stick to the story
3. Say it once and say it well

These apply as well to many other forms of written communication.

Studies of professional journals indicate that most published papers are no better than manuscripts submitted to our committee. The typical paper in the chemical literature, for example, can be cut one-third without loss of a single concept or contribution. Moreover, when papers are so improved, we have found that about one in four contains too little new material to warrant publication at all. The bulk of the chemical literature could thus be cut in half without loss. Such experience as the committee has had with engineering literature suggests that at least an equal reduction could be made there.

A publications committee is effective not only in the achievement of better publications but also as a medium for promoting clearer writing—and the clearer thinking that that requires. Members of the committee and authors who appear before it benefit alike. Gradually the benefits emerge in better writing of internal reports and more precise thinking in the conduct of research. The committee pattern might profitably be adopted by many groups of scientists and engineers.

Conclusion

Combined, our several attempts to improve written communication have required the efforts of less than one man per hundred professional staff members. The resultant improvement can be assessed only indirectly. The opinion prevails that our internal reporting has become noticeably better over the past decade. A further clue is the attitudes of journal editors; over a period during which their standards have supposedly become more strict, our publications have fared better. Perhaps the surest indication is that some of our best writers have returned voluntarily and repeatedly for further assistance. More and more of our scientists and engineers recognize that written communication presents a challenging problem and seek all means at their disposal for solving it.

The prominent weakness of organization suggests that writing ability may not be the sole problem in communication among scientists and engineers. Of the three steps in solving a problem—planning the attack, working it out, and communicating the results—the first and last are related more closely than their positions might suggest. Certainly, a soundly conceived attack is easier to explain than a haphazard one, just as it is easier to work out. Likewise, early recognition that the job will not be done until it is reported argues convincingly for better planning. Perhaps these are simply other ways of saying that often the most productive scientists and engineers are those who do the best job of written communication.

If so, attention to written communication is well worth cooperative effort by supervisors, scientists and engineers generally, and writing experts. The supervisor should devote most attention to those aspects of science and engineering for which his experience best qualifies him: planning the attack and organizing the report. The individual scientist at the bench or engineer at the desk can then apply his ingenuity more intensively to his role: working out solutions and drafting the report. Writing experts

can then direct their talents exclusively to the final step: communicating the results and smoothing and sharpening the report.

Attention to improved written communication can do far more than merely raise the efficiency of scientists and engineers. Efforts of writing experts can catalyze better planning and execution of projects, as well as effect better reporting. Critical editing of publications at the source can halve the costs of publication—a headache to most professional societies today—and at the same time hasten the progress of science and technology. So great is the need and so little is the cost, that attention to improved written communications deserves the serious consideration of all technical organizations.

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EFFECTS OF INTERNATIONAL PRODUCT COMPETITION ON UNITED STATES RESEARCH*

The panel session on effects of international product competition on research in the United States was under the chairmanship of Mr. Philip M. Arnold, Manager of the Research and Development Department, Phillips Petroleum Company. Four papers were presented, each by a representative of his field.

The optical industry was discussed by Howard S. Coleman, Vice President, Research and Engineering, Bausch and Lomb Optical Company. Problems of the chemical industry were presented by Leonard C. Chamberlain, Jr., Assistant to the Director of Research, The Dow Chemical Company. The electrical field was represented by Donald G. Wilson, Assistant Vice-President, Stromberg-Carlson Division, General Dynamics Corporation. T. F. Olt, Vice President-Research, The Armco Steel Corporation, described the effects of competition in steel.

Certain problems of international competition are peculiar to each industry; other aspects are common to all. The traditional element of substantially lower rates of pay for labor in foreign production is quite as evident today as in the past. However, in stark contrast to conditions at the close of World War II, foreign competition is now characterized by modern equipment, able management, high quality research, and aggressive sales outlook.

* Staff report of a session at the Fall 1959 Meeting of the Industrial Research Institute, Lake Placid, New York.

The integrated effect of all of these forces makes itself known in the markets of the world.

The European Economic Community, a vast market comprising France, Italy, Germany, Belgium, Netherlands, and Luxemburg, plans to eliminate all internal custom barriers and quota restrictions over a period of 12–15 years. With a common tariff structure to the outside world, this community will affect international trade to a marked degree.

In addition to the normal elements of international commerce, there are the imponderable aspects of trade inspired by political motives. Ever present is the threat of dumping by the Soviet Union of goods representing the products of practically every industry. A factor whose magnitude can scarcely be reckoned is the growing power of the industrial forces of China.

What other conditions confront particular segments of American industry and what steps have they taken to surmount the problems?

Optical Industry

The competing nations are Japan, West Germany, France, United Kingdom, Switzerland, Italy, Sweden, and East Germany.

Dr. Coleman discussed product groups within the industry. Tabulated data were presented showing domestic production, imports, exports, and ratios derived from these figures (Table I).

Domestic production of all items in the above groups had a value of $329 million in 1958, which is about $20 million more than the total for 1956.

Study of the figures in Table I reveals that foreign competition has had the most effect on the product groups of greatest aggregate value. For example, still and motion picture cameras and photographic lenses sold separately from cameras are items of which the imports greatly exceed the exports. Further, the imports of cameras amount to about 16% of domestic production

and therefore exert a determining influence upon the domestic prices.

TABLE I

Production and Trade Figures for the Optical Industry[a]

	1956	1957	1958
Ophthalmic lenses			
Domestic production, $	37,000,000	38,000,000	40,000,000
Imports, $	317,000	306,000	390,000
Exports, $	937,000	1,155,000	1,168,000
Ratio imports to exports, %	33	27	33
Ratio imports to domestic production, %	0.9	0.8	1.0
Ophthalmic frames			
Domestic production, $	95,341,000	101,609,000	98,411,000
Imports, $	3,426,000	4,323,000	3,969,000
Exports, $	6,933,000	7,069,000	6,006,000
Ratio imports to exports, %	49	61	66
Ratio imports to domestic production, %	3.6	4.3	4.0
Still and motion picture cameras			
Domestic production, $	115,990,000	122,529,000	131,294,000
Imports, $	17,422,000	20,932,000	21,362,000
Exports, $	5,983,000	6,234,000	6,655,000
Ratio imports to exports, %	290	340	320
Ratio imports to domestic production	15	17	16
Photographic lenses			
Domestic, $	50,000,000	55,000,000	60,000,000
Imports, $	3,695,000	4,761,000	4,320,000
Exports, $	1,945,000	1,374,000	1,584,000
Ratio imports to exports, %	190	347	273
Ratio imports to domestic production, %	7	9	7

[a] Data provided by Marketing Research Division, Bausch and Lomb Optical Company.

With regard to ophthalmic frames, the ratio of imports to exports increased from one-half in 1956 to two-thirds in 1958.

However, the imports appear to be stabilized at about 4% of domestic production. International competition has affected ophthalmic lenses to a lesser degree. Imports remain at about one-third of exports and at 1% of American production.

Japanese binoculars have, in recent years, achieved nearly a world-wide monopoly. The success may be attributed not only to the far lower cost of labor in Japan, but also to the aggressive build-up of a world market for cheap binoculars which formerly was not exploited. In the process, the Japanese captured the lion's share of the market for the more expensive type.

West Germany was the principal exporter of microscopes until 1954. Since that time, Japan has assumed the leadership, with particular strength in the cheaper products of subprofessional and toy grades.

Certain instruments used for testing and quality control form an important group of products in the optical industry. In many cases the instruments are built into manufacturing processes and their use becomes an essential step in production. Formerly, buyers demanded products of domestic origin in order that any necessary repairs could be quickly accomplished and high accuracy readily maintained. Continued production demanded prompt, effective servicing.

However, in these days of rapid communication and travel, foreign producers are becoming increasingly successful with sales backed up by local service organizations. Trade figures reveal that domestic production of instruments is increasing, but at a slower rate than the imports of foreign products, and in general, it has become evident that the encroachment of foreign goods upon markets which were formerly held securely by American manufacturers has become a matter of serious concern to the industry.

Response to Competition

Optical research in countries of Europe, has traditionally been of a basic, fundamental nature—more so than in this country.

We have made the greatest contribution to product and process development and engineering. In response to foreign competition, we have increased our efforts toward exchange of information through the media of professional journals, attendance at international meetings, and personal contacts with scientists abroad.

We have increased our research effort and directed a portion of it along the lines of cost reduction with safeguard of quality. Recently, for example, American research and development have advanced the use of novel plastic materials for manufacture of ophthalmic lenses and frames to obtain improved products at lower cost. We have produced distinctive frames by use of colored anodized aluminum as replacement for gold-filled materials. Other areas of research are being actively cultivated.

The American optical industry has, of late, sponsored a substantial amount of research abroad at universities, research groups, and at the subsidiaries of parent companies. Two conditions have contributed to this trend. First, there is a shortage of qualified scientific personnel in this country, and secondly, the cost of research is lower at the overseas locations. The contracts are generally administered by the research and development organizations of the American companies.

The American optical industry has found it necessary to establish manufacturing plants abroad. These are located in quite a few areas of the free world where skilled labor and technical and scientific skills are available. Some of the plants are wholly-owned subsidiaries of American companies, others are affiliated with foreign producers. In the past, the output of these plants was devoted entirely to the maintenance of overseas markets. Lately, domestic manufacturers have imported parts and assemblies for distribution here.

We have intensified our efforts at patent protection as another means of coping with international competition. Far more than in the past, attention is given to obtaining design patents and patents dealing with mechanical linkages and relationships of

optical parts. We want to guard against the free utilization by others of discoveries made at the expenditure of much time and money.

Chemical Industry

Mr. Chamberlain outlined the development in this country. Our chemical industry, which was relatively small during the early years of this century, received its great impetus to growth in World War I. Twenty-odd years later, when the nation faced another and greater struggle, the American chemical industry demonstrated to the world that it had attained full maturity.

Chemical and allied products constitute a group frequently treated as a unit for statistical purposes. Included in the group are the subdivisions of industrial chemicals, coal tar chemicals, pharmaceuticals, plastics, fertilizers, crude drugs, soap and toilet preparations, and paints and pigments. Total sales of all products in the group are valued at about $25 billion annually.

All categories, with the relatively minor exception of crude drugs, have had a remarkable upsurge of exports during the years which followed World War II. In 1957 the combined value of the exports reached an all-time high of $1.5 billion. The lowest value was about $800 million in 1950.

Imports have ranged in value from 30 to 48% of exports and, while the figures for exports have shown a fairly consistent upward trend, the imports do not have that showing. The low ratio of import to export (30%) occurred as recently as 1958. The general trend, however, has not been downward.

During the post-war years, the value of imports has never exceeded 3% of the total United States sales. Production and trade figures for selected categories are presented in Table II.

The figures reveal the overall strength of the industries concerned. Today, the giant organizations which manufacture chemical and allied products face some intriguing problems in safe-

guarding and improving their positions in the face of increasingly intense international competition.

In contrast to the general showing, there are more than a few specific instances where imports have had severe, even crippling effects on domestic products. With reference to the Dow Chemical Company, Mr. Chamberlain stated that imports have affected the volume of sales, the prices, or both volume and price of 16 products. The company, for example, decided to discontinue the manufacture of antipyrine because of German imports. Profits

TABLE II

Foreign Trade in Chemical and Allied Products[a]

	1947	1951	1957	1958
Coal tar products				
Imports, $	11,514,000	53,791,000	57,883,000	60,167,000
Exports, $	120,860,000	77,693,000	91,132,000	101,068,000
Ratio imports to exports, %	9.5	68.9	63.3	59.5
Medicinal and pharmaceutical preparations				
Imports, $	7,459,000	11,823,000	11,594,000	15,132,000
Exports, $	177,039,000	281,382,000	284,537,000	277,661,000
Ratio imports to exports, %	4.2	4.2	4.1	5.4
Industrial chemicals				
Imports, $	34,501,000	120,045,000	84,788,000	86,969,000
Exports, $	160,209,000	172,397,000	218,858,000	214,482,000
Ratio imports to exports, %	21.5	70.0	38.7	40.5
Soap and toilet preparations				
Imports, $	4,733,000	5,847,000	9,438,000	8,812,000
Exports, $	41,314,000	19,861,000	23,708,000	21,950,000
Ratio imports to exports, %	11.3	29.4	39.6	40.2
Fertilizer materials				
Imports, $	43,453,000	101,923,000	97,116,000	97,181,000
Exports, $	35,609,000	50,677,000	135,319,000	109,472,000
Ratio imports to exports, %	122	201	72	89

[a] *Chem. Eng. News,* 85, Sept. 7, 1959.

in iodine have been seriously affected by Japanese and Chilean products. Undoubtedly other companies have encountered similar cases.

World War II brought conditions of deterioration and ruin in many of the foreign centers of chemical production. Manufacturing capacity was utterly inadequate to supply the needs of the time. Capital was lacking. Under the circumstances, management was more than willing to trade know-how for cash. Further, many technical experts were eager to leave their homelands for work in this country. Accordingly, our chemical industry purchased know-how, hired the experts, and established effective liaison with industry abroad.

With recovery of the foreign economy—catalyzed in great measure by American aid—foreign industry regained and surpassed its prewar capacity. Scientists became less willing to leave their native lands, and foreign industry concentrated not on the sale of novel processes, but rather on the sale of products of their manufacture. They demanded participation in American as well as the other markets of the world. Chemical industry abroad has, in fact, fully overcome its recent handicaps, and the companies operate as formidable competitors with able technical and managerial talent, skilled labor, and modern plants and equipment. Clearly, the paths of the domestic producers are now beset with obstacles which make further advances more difficult than in the past.

Response to Competition

In response to international competition, our chemical industry has redirected part of its research efforts toward the products most affected. Particular attention is given, for example, to process improvements to lower the cost of production in order to offset the advantage in cost of labor of our foreign competitors. Quite generally, the factor at issue is price; our products are equal or superior in quality to the foreign counterparts.

As with the optical industry, there is a decided trend toward establishment on foreign soil of affiliates or wholly-owned subsidiaries. The pharmaceutical industry, which has had a particularly high ratio of exports to total sales, was a leader in the establishment of manufacturing operations abroad. Chemical industries have followed. Today, there are plants in foreign countries which are wholly or partly owned by many American chemical companies. In 1953, about 6% of investments by the chemical industry, were placed abroad. At present, the percentage is about double. The Dow Chemical Company intends to place overseas 15–25% of its new capital investments.

In addition to production units, chemical industry has established about a dozen research laboratories abroad. They are generally manned by foreign scientists, and suitable liaison is maintained with the American headquarters for research. The cost of operation of the foreign laboratories ranges from 40 to 80% of that of comparable research facilities here.

International competition has been a source of stimulation to our research people. They have become more international-minded. During the past decade, they have studied foreign languages and made many trips abroad. They have evaluated technical developments, negotiated the sale of information, organized research laboratories on foreign soil, and recruited scientists to work in them. Our research people have been assigned to plants and laboratories overseas, they have developed personal contacts, and received most of the foreign visitors.

Today, the industrial areas of the world are nearly all within "commuting" distance of each other. International communication is about as rapid as desired. People have far better opportunities to learn what is going on in the other fellow's backyard—wherever the yard may be. All of these conditions give emphasis to the need for more international patent protection.

The cost of foreign patent protection is considerable. It becomes necessary to define more clearly the utility of an inven-

tion, the scope of coverage, and the extent of advantage over known alternate routes. Dow's experience points toward a policy of delay in the filing of foreign patents. The added time is utilized to acquire more information and to assess the results of the patent application in this country. The increased knowledge results in the filing of more effective claims in foreign patents.

The whole subject of foreign patents is fraught with difficulty and complication. Subjective factors enter into the decisions made, and it appears impossible to always take the right course, or even to maintain a consistent policy. Foreign law generally allows relatively little time between publication of results and filing of claims. In order to obtain more information, it becomes necessary to delay publication, and this delay is considered by our research people to be one of the unpleasant features of international competition.

A recent article in a chemical engineering periodical stated that the industry has become "alarmed and intrigued" by the revitalized chemical industry abroad. Our research people are far from alarmed. They have become stimulated and intrigued, for international competition has spurred their efforts, broadened the horizons, and given them more opportunities to participate in management decisions.

Electrical Industry

During the past year, certain manufacturers of heavy electrical machinery appealed to the Office of Civil and Defense Mobilization to curb the imports of foreign products on the grounds of national security. The action was taken because vital productive capacity of the nation would, according to the appellants, be impaired if events were permitted to continue.

Dr. Wilson mentioned, for example, the case in which the Tennessee Valley Authority awarded a contract to an English company for a large turbogenerator on a firm bid of $12.1 million.

The lowest American bid was $17.6 million and it was not firm since the proposal contained an escalator clause adapted to a cost index. On another occasion, a purchase request by the Army for turbines was followed by award to a foreign producer on a bid of $6.5 million—about one-third less than the lowest domestic offer. As a third instance, an English company was successful in an invitation to bid on a turbogenerator installation in Arkansas. The price of $1,450,000 was $300,000 less than the lowest American bid.

With regard to the last-mentioned incident, the Office of Civil and Defense Mobilization decided that interest of national security dictated award to the low United States bidder. That office ruled subsequently that, in general, the imports of heavy electrical equipment did not constitute a threat to our security.

The inroads of foreign competition are, of course, not confined to heavy equipment. Electronic products, for example, have also been severely affected. For the first nine months of 1959, imports of the latter totaled $48.8 million, which is more than $2^1/_2$ times greater than the imports for the entire previous year.

An American company recently entered into a contract providing a substantial option on electronic medical instruments of Russian make. The progress which Japan has made in electronic products is revealed in the following figures showing the value of her exports to this country:

1956:	$ 3.3 million	
1957:	7.6 million	
1958:	21.8 million	
1959:	22.1 million	(first six months only)

Japan's production of transistors has increased remarkably. In at least one of its plants, all processes are automated except for the welding of a contact. The personnel requirements of that plant were reduced to one-third of that formerly needed. Other electronic products in which Japan has shown particular strength

are diodes, thermistors, condensers, and radios—principally of the portable transistor type.

On the petition of the Electronics Industries Association, the Office of Civil and Defense Mobilization in 1959 ordered a formal investigation of imports of transistors and related products. The purpose was to determine whether the market established here by foreign manufacturers, principally Japan, constitutes a threat to domestic producers and the national security.

Response to Competition

This industry has always shown particular strength in development of new products. These *research-intensive,* as distinguished from *labor-intensive,* goods have made possible the building up of a world market for products which either did not exist previously or which represented decided improvement over old

TABLE III
World Trade in Electronic Equipment[a]

Country	Portion of world trade, % 1957	1958
United States	31.1	28.9
West Germany	21.1	21.3
United Kingdom	20.5	19.8
Holland	6.2	7.0
France	5.7	6.7
Belgium–Luxenburg	3.3	3.4
Japan	2.6	3.0
Switzerland	2.6	2.7
Sweden	2.4	2.5
Italy	1.6	1.7
Denmark	1.0	1.1
Austria	0.9	1.0
Canada	1.0	0.9
Total	100	100

[a] Data from *Electronic News,* March 21, 1960.

products. When the stage of standardized production is reached, the usual conditions of cost begin to govern, and foreign plants have the advantage. The answer to international competition is to intensify and broaden the research base in order to lead the world in new developments.

At the present time the United States leads in international trade in electronic equipment, but our position is under threat as shown by the data of Table III.

The figures reveal that all of the countries of the European Economic Community as well as Japan, Switzerland, Sweden, Denmark, and Austria, have attained an increased share of the world trade. This was accomplished at the expense of Canada, United Kingdom, and ourselves. The American electrical industry intends to reverse this trend by aggressive sales efforts fortified by vigorous and expanding research.

Steel Industry

Mr. T. F. Olt, Vice President-Research, Armco Steel Corporation, gave some background data on the industry. The 82 producers of ingots in the United States have a capacity of about 147 million tons annually. The companies differ enormously in size. The capacity of the largest is 42 million tons annually; of the smallest, 7,000 tons. Most of the companies have a capacity of less than 500,000 tons annually.

Total investment in the steel industry is about $13 billion. During the past few years, annual sales have equalled or slightly exceeded the investment. However, the first half of 1959 was a record-breaking period with sales at the rate of $1.50 per dollar invested.

Nations that are bent upon achieving industrial maturity give particular attention to their capacity for making steel. In the period 1947–59, world production more than doubled. The rate of increase was very much greater in the Soviet bloc than in this country. For example, in 1947 we made more than 50% of

the world production of steel. The Soviet Union and other countries of Eastern Europe produced about 15%. In 1958, the United States contribution was about 28%, while the Soviet Union and its satellites raised their share to 26%.

Recent statistics on industry shipments, imports, and exports of steel mill products show the effects of foreign competition. A summary giving overall figures is presented in Table IV.

The figures for the first three years reveal the gradually increasing strength of foreign competition and the last three years show an accelerated growth of its effects. December of 1958 marked a turning point, for in that month the total of imports began to exceed that of exports. With respect to certain products, such as reinforcing bars, wire nails and staples, barbed wire, woven wire fence, and drawn wire, imports have exceeded exports for the entire period covered by Table IV. Our strength in exports has been in such products as sheets and strip, plates and structurals, rails and accessories, tubing and pipe, and tinplate.

TABLE IV
Production and Trade in Steel Mill Products[a]

	1954	1955	1956
Industry shipments, net tons	63,153,000	84,717,000	83,251,000
Imports, net tons	784,000	970,000	1,334,000
Exports, net tons	2,659,000	3,871,000	4,157,000
Ratio imports to exports, %	23	25	32
Ratio imports to industry shipments, %	1.2	1.1	1.6
	1957	1958	1959
Industry shipments, net tons	79,895,000	59,914,000	69,377,000
Imports, net tons	1,153,000	1,703,000	4,392,000
Exports, net tons	5,175,000	2,687,000	1,508,000
Ratio imports to exports, %	22	63	291
Ratio imports to industry shipments, %	1.4	2.8	6.3

[a] "Foreign Trade Trends—Iron and Steel," American Iron and Steel Institute.

Two important elements in the price of steel are the cost of raw material and the rate of pay for labor. The relative advantage among nations of raw material costs is difficult to assess, but the figures for labor cost are more definite. Table V presents the hourly earnings of steelworkers in various countries on the basis of United States currency.

The figures reveal that the average hourly earnings in this country are by far the greatest, being more than three times that of the next highest nation, Luxemburg, and more than seven times the average rate of pay in Japan. These differentials in the cost of labor illustrate the difficulties faced by the American steel industry in competing with foreign producers on a price basis.

Response to Competition

Research in steel is conducted vigorously in the principal producing nations. In Europe, the work has been largely on a cooperative basis at the various national industry organizations as, for example, the British Iron and Steel Research Association. Here in

TABLE V

Average Hourly Earnings and Employment Costs, Steel Industry, 1957[a]

Country	Average hourly earnings	Total hourly employment cost (estimated)
West Germany	$0.67	$1.00
Luxemburg	0.89	1.29
Belgium	0.775	1.04
United Kingdom	0.805	0.90
Japan	0.406	0.46
United States	2.917	3.22

[a] Sources: European Coal and Steel Community, Bulletin Statistique, November 1958; British Iron and Steel Federation, Iron and Steel, Annual Statistics, 1957; Japan Iron and Steel Federation, Annual Report for 1957; International Labor Organization, International Labour Review, Statistical Supplement, June 1958; American Iron and Steel Institute, Annual Statistical Report, 1957.

the United States, each company does its own research, some fundamental work being sponsored cooperatively by the membership of the American Iron and Steel Institute.

It is characteristic of the American steel industry that changes in manufacturing practices are evolutionary in nature. The high capital cost in steel plants militates against major investment for innovations unless correspondingly large gains can be achieved. Our conditions of production make new process development a highly speculative venture. We have, instead, devoted considerable attention, with successful results, to the improvement in productivity of existing equipment.

In most foreign countries, the production units are frequently relatively small, and changes in processing can be accomplished without excessive penalty in added cost of labor. It is largely for these reasons that most of the new steelmaking processes have been developed in foreign countries. The creation of electrical steel, tinplate, and stainless steel, the employment of oxygen for elimination of metalloids in steelmaking, and the modifications in Bessemer blowing by use of combinations of oxygen with steam or carbon dioxide under various conditions are all European developments. Improvements in ironmaking involving operating procedures and new processes for working of raw materials, iron ore, and coal have also been developments essentially of European research.

We have made significant contributions to the development of new products and in extending the fields of application for steel. We have led the world in design and production of rolling mill equipment as, for example, the wide strip mill for rolling sheets. An important American development in ironmaking was the pelletizing of the fine concentrate from taconite rock which made possible the recovery of iron from this low-grade ore.

One response to international competition has been the development of wholly-owned subsidiaries abroad, as well as companies owned jointly with foreign producers. The Armco Inter-

national Corporation for example has been active for many years with operations in countries outside the Iron Curtain. Another response has been an expansion of research activities. We have always led in the development of new products and we are determined to maintain the leadership.

We are giving increased attention to licensing arrangements involving technical aid for use of the discoveries arising from our research. Included in this program are grain-oriented electrical steels, metallic coating processes for sheet and strip, and stainless and heat-resisting steels. We have increased our liaison with foreign research establishments by frequent exchange of visits by the research people in the industry. The American steel industry will retain its position by intensifying its efforts in the development of new products and new applications for the world market.

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PROCEEDINGS OF INDUSTRIAL RESEARCH INSTITUTE STUDY GROUP MEETINGS. NUMBER 1. THE ENVIRONMENT FOR CREATIVITY*

Reported by
JAMES A. BRALLEY
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PHYSICAL FACTORS AFFECTING CREATIVITY

Stimulating Associations

A number of company practices fall under this head. The system of sabbaticals and exchange of laboratory personnel, mentioned under the heading, Recognition and Rewards, are valuable for their stimulating association with other workers. In this vein, one company also sends their men out into their production organizations on one-year rotating assignments so that they may become more familiar with problems in the field.

Several felt it is advantageous to scramble people of different interests in order to stimulate activity and bring about better and more widely applicable inventions. As an example of this, they

* Concluding portion of this report. The first part of the report was published in *Research Management,* 3, 97–122 (1960).

put a physical chemist in the laboratory with a group of synthetic organic chemists, or an organic chemist in a laboratory with a group of physicists. In a similar way, it has been found very helpful to hire university professors and even high school science teachers for the summer months. University graduate students are also taken in on the same basis. Also, several companies have found by experience that it is good practice to put a very creative individual in close proximity to a more conservative one who can sift the wheat from the chaff of the creative person's ideas and help tremendously in developing them to ultimate success.

Several companies having a big turnover in technical people find that sending personnel to other divisions of the company where they are better suited gives them a tremendous advantage in isolating and keeping the most highly creative individuals. At the same time, it provides a constant flow of highly competent technical people to the rest of the company and an influx of replacements of varying creativity for the research department itself.

Many of the conferees strongly recommended giving a research man a rest from a particular problem by shifting him to another. Six months later, he may be able to attack the older problem with a fresh outlook and solve it in a relatively short time.

One man said he does not worry too much about hiring creative people, because they have found that in the natural course of events they come up with enough men of this sort. Since one creative person can keep 50 people busy exploiting his discoveries, they cannot afford to have too many creative individuals.

This remark lead to a discussion of the best means of choosing creative people during an interview. Most of the conferees felt that the best ones to do this are the most creative people in the laboratory themselves, as they tend to recognize this quality. For many laboratories, this has become the principal means of selecting the research people they wish to hire. Most companies represented do not worry about a man's outward appearance or working habits, provided he is truly productive. A nonconformer is also likely

to be a divergent thinker and, therefor, frequently a creative person.

Tolerant Management

The study group attendees felt that management's attitude is an environmental factor that has been inadequately discussed in the past. It was agreed that on occasion when management has indicated to the research group what areas should be emphasized, research does not always agree with these directives, and does not necessarily follow them, but they are taken into consideration along with all the other information that is at the disposal of the research men in making a final decision.

It was pointed out that research management is the only means of appeal that scientists have to upper management; if research management is not able, it can wreck the research effort. One of the principal purposes of the top research administrator's job is to act as a buffer between company management and research people and try to reach agreement on projects to be studied in the research program and the way in which results should be handled.

Some people felt that research management is completely responsible for setting the attitude of top management in the company, but others felt that, because of the somewhat parental relationship of top management to research management, it is too late to expect a change in this direction. The variation in atmosphere from one laboratory to another, even in companies in the same line of business, depends on the degree of maturity of management and its approach to research. The best way to make really startling contributions to old technology is for management to institute a broad program of fundamental research, financed heavily over a long period of years, so that the new basic knowledge eventually can be utilized in revolutionary applications. It takes a tolerant and patient management, well versed in the philosophy of research, to persevere in such a program.

A relatively small matter in which management has an op-

portunity to exercise tolerance is in the question of working hours and the discipline problem involved here. One company solves this problem very neatly by having a nominal starting time about 30 minutes before the true official starting time. The workers are not aware that the official starting time is 30 minutes later and that nobody really cares if they are 10 to 20 minutes "late" getting to work. This device gets around the necessity for having time cards or punching clocks. Where time clocks are in use, it is important that all people working in that location, including top supervisors and management, punch in and out as does the lowliest hourly worker. Most of the conferees agreed, however, that doing away with time clocks entirely is a very inexpensive means for management to promote good will and high morale among the research staff.

Physical Facilities Increase Creative Efficiency

Everyone conceded that good physical facilities, though not able per se to cause an increase in creativity, might increase the efficiency of the creative act. It was recognized that laboratories come in all sizes, classes, and degrees of quality. The question is, to what extent does this affect the creativity?

The question of new laboratories versus old ones was discussed first. One man remarked that a number of years ago his company had several laboratories scattered around the country. At this time, the research men were reluctant to buy the new tools available and hesitant to buy any very expensive equipment. Since then the laboratories have been centralized in a large, new building, and the men are now much more willing to buy equipment and have even been very productive in designing and making their own unique tools.

A large appliance manufacturer has a new laboratory which attempts to give each professional worker his own personal module, with a desk and telephone to insure privacy. The module is 12 × 18 ft. All supervisory personnel and theoreticians who do

not use laboratory bench space have private offices with a blackboard on the wall. Each professional man has a laboratory assistant. Professional draftsmen are available to draw graphs or draft working drawings from pencil sketches made by the scientists.

Many people felt that although good laboratory facilities help in recruiting and increase the total output of work, they are not essential to the creation of ideas. Several instances were pointed out where organizations having extremely high creative records and good morale are cramped in their quarters. Although they have very fine physical equipment and plenty of it, the working quarters are quite unsatisfactory from an aesthetic standpoint. Companies that have designed more seminar spaces into their new laboratories have found this helpful in stimulating creativity.

The importance of good housekeeping in the laboratory was discussed next. Most people agreed this is very desirable but admitted it is hard to attain. It was also agreed that there was no firm correlation between neatness and creativity. Several men found that periodic and frequent visits by the top brass of the company are a good stimulus to cleaning up the laboratories. Annual visits by the president of the company and biannual open-house days result in a very good clean-up of the laboratory, and this is about all they try to do. Most companies tie safety inspections in with cleanliness.

Several of the conferees stressed that they now obtain much better service from their own research laboratory shops, which are nonunionized, than they did formerly when they had to depend upon the manufacturing plant's shop people, who were unionized.

Technical help in the form of laboratory assistants for both creative and noncreative scientists was considered essential. Apparently, the ratio of technicians to scientists varies all the way from four technicians per scientist, in some cases, to as low as one technician for every three scientists. The consensus of the group was that each individual situation should be considered on its own merits. Technicians present a problem when the nature

of the work changes and men have to be shifted to other supervisors. Often scientists consider the supervision of technicians to be a symbol of their status in the organization; also, the technicians prefer working for a senior scientist rather than another technician running routine operations.

The importance of equipment as a physical factor varies from industry to industry. It is extremely important to electronics people but not quite so important in the chemical industry. Occasionally, equipment can be a handicap to creativity in that measurements sometimes become a routine operation and the worker does not bother to look into the cause of a particular phenomenon.

In discussing library facilities, all the companies represented said that they buy, without question, all the books their people request. Foreign language articles are often translated for the scientists. In some cases laboratory personnel skilled in foreign languages pick up some extra pocket money by making these translations for other members of the staff on their own time. The general feeling is that not enough people use the library. Physical location of the library is important; for example, if it is near the cafeteria more people use it than if it is located in another building. Many libraries route to all the research men each week title pages from each journal received. This saves the scientists the trouble of going to the library to see what is in the new journals.

It was acknowledged that better means of information retrieval from the literature can probably save companies enormous research expenditures. There was a feeling that foreign laboratories are more successful in this than American ones because the personnel receive better training in languages.

Community Surroundings

Closely allied to the problem of physical facilities is that of community surroundings and the communication and psychological problems these entail.

Many companies have, in recent years, built large research centers in suburban or university communities, with the idea of separating their research people from the production units of the company and thus avoiding day-to-day fire-fighting problems, which are quite a hindrance to basic research. Many of them, however, now feel they have lost much by not having the fundamental research people in close contact with advanced development people. Therefore, the trend seems to be reversing itself somewhat, and development people are being brought into the research centers in order to create a more diversified technical center. The consensus is that this policy of having people working on long-range projects in relatively close proximity with development people who are concentrating on short-range goals is a good arrangement. It is helpful in getting a development from research to the commercial stage in a much shorter time than is usually possible in other situations.

The advantages of having a research center in a university community are manifold and quite apparent. The availability of a number of persons of high intellectual level in the neighborhood is very desirable and exchange of ideas with the university staff is a great aid to the creativity of the research worker. Part-time technicians and summer employees are usually readily available in a university community.

The advantages of having the laboratory in close proximity to the factory or to competitors in the same field of work are often offset in metropolitan areas by the difficulty of commuting. When men have to drive a long distance from suburban homes to the laboratory, they usually travel in car pools or by scheduled public transportation. Thus commuting imposes a definite restriction on the individual's freedom to come and go. There may be a slight compensation in the helping of communication between workers involved in the same type work, but certainly a limitation is put on the freedom of working hours under these conditions.

The advantage of having technical centers in suburban areas

where country club facilities, such as swimming pools or golf courses, are near the laboratory, was discussed briefly. Some people said that frequently, on week-ends, men bring their families out to the pool or golf course and leave them there while they duck into the laboratory for a few hours of concentrated work. Admittedly, this is not done widely, but it may be a neglected possibility. The feeling was again expressed that exterior surroundings of beauty are relatively unimportant to creativity. There are numerous examples of extremely fine creative work coming out of surroundings that are very unattractive.

Communications: Extremely Important but Can Be Overdone

The study groups emphasized the importance of verbal communication over the written word. They were very definitely of the opinion that written communication can be carried to such an excess that it becomes an important inhibiting influence on creativity.

It was emphasized that cooperation between sales and development people for exchange of ideas is extremely important in the generation of new ideas and carrying them through to finished products. Communication is a principal problem in effecting this end result. One company has found it useful to have periodic meetings of market research, product development, and a project analysis group with the research department, to make sure they are completely informed on all aspects of the practical considerations bearing on their research developments.

Several people emphasized the importance of direct contact between men working at the same level for exchange of ideas and help on their individual problems. This can be facilitated with periodic meetings and reports horizontally circulated. One organization has a working rule that anyone can talk directly with anyone else in the company about his problem in an effort to get help on it.

It is extremely difficult for management to turn down a high

proportion of good ideas because it cannot afford to develop them and still keep a free flow of ideas coming out of the research department. Management must pass the company decisions on to the research worker, and make sure that he understands why a specific decision was made.

It was brought out that the project system, whereby one man may supervise a development going on in a number of divisions of the company, is a strong factor in promoting communication.

It was pointed out that the best way to handle nonconformers is to be sure they are thoroughly acquainted with the problems of the company and that they understand the needs of management. Again, this is primarily a question of good communications. Many felt that the nonconformer has a better time of it in industry than he does in university laboratories where it is necessary for him to establish a certain rapport with students.

Communications can become very important in handling salary administration matters. One research director told of a recent incident where he had, after considerable discussion with his upper management, been able to get a $1,200 raise for a man already at the $16,000 level. When informed of his raise, the man was highly insulted by the amount of the increase. When it was explained to him that he was one of the dozen highest paid people in the whole department and when he was shown what sort of salaries some of the company executives were making, the man became quite happy with the size of his raise. His initial reaction was due simply to the fact that he had no frame of reference for judging his own remuneration. When he finally became aware that he was being treated very fairly, he no longer felt bad about the amount of his raise.

There are, of course, many mechanisms for communications; but the groups agreed that day-by-day personal and verbal contacts, with a minimum of formal written reports, is the most effective and efficient way to communicate. It was emphasized that lateral communication should be free among the re-

search workers and also with other divisions of the company concerned with new developments.

Psychological-Environmental Factors Affecting Creativity

Consistent Progressive Behavior as an Environmental Factor

The study groups felt that a research organization should show a *dynamic* stability; that is, it should continue to grow in quality and effectiveness, although not necessarily in size or the number of people. One person termed this "diligent procreation of the staff," i.e., the replacement of men lost to sales, production, and other divisions of the company with constantly higher caliber and more creative workers. All the conferees felt that stability of growth of the organization is important, both to the research workers already there and to men considering going with the company directly from college or graduate school. If the company has a long-term record of consistent belief in and use of research and efficient research management, this can be of prime importance in recruiting new scientists and in keeping a high morale among the older staff. Such consistent progressive behavior enhances the reputation of the company and promotes the professional status of its research staff.

Recognition of the Right Time Constant

A hitherto unrecognized environmental factor in creativity, or at least an unexpressed and seldom discussed factor, is the right time constant for a particular research problem. Some of the conferees were, at first, reluctant to admit the possibility of this time constant being a real factor in the environment for creativity; but after some discussion, most of them acknowledged there may be a real problem here. They conceded it is important that problems be studied in laboratories suited to the particular period

of time the nature of the problem may require for solution. That is, some laboratories work on short-term problems of three months or six months or one year's duration; other laboratories are strictly long-term, of the two-year, five-year, or ten-year program type. Often the problem may be diagnosed initially as a short-term problem requiring some six months' study. Then, as one delves deeper into the intricacies it becomes apparent that it is a problem which will require a much longer and more elaborate program for solution. At this point, it should be shifted from the short-range lab to the long-range, more fundamental research laboratory. This, of course, usually involves a change of personnel working on the problem. The planned length of the research program is important in giving freedom of action to the researcher. Usually, the longer-term programs are those in which the bench worker has a more significant voice in the future of the project. Workers differ in their suitability for studying programs of varying duration. A man who works effectively on one problem for a short time, but who loses interest as it develops into an involved situation, should not be in a laboratory where fundamental long-term programs are the rule. On the other hand, men who do best on long-term problems should not be assigned to a laboratory where all of the jobs are of relatively short duration.

Removal of Inhibiting Factors

Everyone acknowledges that excessive red tape has a severe inhibiting influence on creativity. Research managers can help minimize this factor by consistent behavior on all administrative matters. The most common question to research administration is: "How do we handle such-and-such a matter?" These are not technical questions but matters of budgets, reporting results, or decisions about when to do certain administrative chores. This can be met by setting up a consistent policy on all such matters.

Everyone agreed that the best procedure in a large organization is to give a straightforward presentation of all the facts

and let the chips fall where they may. This is being consistent and it avoids tripping oneself up at a later time with inconsistent behavior.

The introduction of two ladders in a research organization, that is the professional ladder and the administrative ladder, has been very effective in removing the burden of administrative chores and paper work from the shoulders of the more creative research workers. Indeed, this is one of the most important arguments in favor of having two ladders of advancement in a research organization.

Acceptability of Output

Several of the conferees mentioned acceptability of output as being an environmental factor affecting research. By this they meant that a research department can be completely demoralized by a hypercritical attitude on the part of other divisions of the company. This happens, perhaps most frequently, in the attitude of sales toward research developments. Often the sales department is reluctant to accept a new development from research if it requires a new sales organization or distribution system. This raises a barrier between research and sales which has an adverse effect on creativity. A similar reluctance on the part of manufacturing divisions to modify current processes according to the latest findings of research is a well-known deterrent to creativity.

Organizational Factors Affecting Creativity

Permissive vs. Authoritarian Atmospheres

One of the most intriguing questions discussed by the study groups was the difference in creativity between laboratories organized under an authoritarian regime and those organized to have a permissive atmosphere. A decision as to the relative

effectiveness of these two types of organizations was not made because of the lack of information for comparisons. It is known that the approach to creative effort of industrial laboratories in Europe, and especially in Germany, is directly opposite that of American laboratories. In Germany, the group leader is authoritarian and very dictatorial in the way he runs his group; everyone works at the specific direction of the group leader. Nevertheless, there is a long record of creative accomplishment.

Other factors may be operating in Germany which have overcome the inhibiting influence of the authoritarian approach. It is impossible to say how the individual research workers, themselves, would choose between the two atmospheres, assuming they were equally familiar with both. However, one of the conferees says that he has several times observed the following pattern in people coming from Germany to work in America. When they arrive in the United States, they work in an industrial research laboratory here for two or three years and then can hardly get out fast enough. He thinks the principal reason is that the man and his wife are disappointed at the lack of prestige they have in the community, and there may also be some language barrier. Nevertheless, they go back to Germany, stay there for one or two years, usually in a higher position than they formerly enjoyed, and then come back to America again and are quite happy to stay here the second time. Having made a direct comparison twice, they usually come to the point that they like the American system better.

Some of the conferees felt it is not possible to have a creative laboratory in this country operated on a strictly authoritarian basis. Others disputed this, saying that there are such American laboratories in existence and that they do highly creative work.

In reference to the Soviet system, it was pointed out that Russian scientists have enormous incentives in the way of freedom and remuneration. The spread between the salaries of a technical worker and the director of the laboratory is some 10- to 15-fold,

whereas in the United States the salary of the director may be two to five times that of the technician. Also, individual Russian scientists have an unusually large amount of freedom of action in planning and conducting their work. There was a general feeling that the Germans are more creative than the Russians in fundamental research, but they are not as creative or successful in the developmental area.

A Loosely Organized Central Research Department

One of the participating research directors described the flow pattern for an idea evolving into a finished commercial product at the laboratory of a large electronics company. The base of the pyramid is the large fund of technical information on specific materials available to the researchers. Devices or components are then derived from this knowledge and these materials. Next, these devices are combined into a particular apparatus and, finally, several apparatuses are used to make a system. The entire research organization is laid down over this flow pattern of development. Hence, people at the fundamental level, i.e., those working on materials, are the ones most responsible for deciding what sort of research use should be made of their work. They are the people best acquainted with the specific properties and peculiarities of the starting elements and are best equipped to lay down the lines of future development research. Management cannot usually have very much influence on the direction this research will take.

This particular research department is organized under a research director who has five laboratory directors under him, each having some 50 to 100 people in his section. Each lab director has two to three assistant directors, and there are research supervisors, without formal title, below these. There is a parallel administrative ladder providing services to the research departments. Some of the lab directors are in fundamental research, whereas others are directing developmental research projects.

Resignations average only about eight per year out of a staff of 300. Usually, only two people per year are fired. However, about 25 people per year are lost by transfer to other divisions of the company. The study group members felt this sort of horizontal organization has one inherent disadvantage, namely, the difficulty of removing an inefficient person who becomes entrenched in a relatively low position.

The loosely organized structure just described is the central research laboratory of the company and serves all divisions which need it. The director does not feel the organization, as such, has very much influence on the creativeness of the individual scientist. The laboratory directors, who have some 60 technical people under them, are responsible for and are intimately acquainted with all the technical work going on in this group. They can discuss the problems in great detail with the research director or with parallel people in other parts of the organization. Salaries of all people below the lab directors are put on the same salary administration set of curves. No distinction is made in sublevels, such as group leaders, subgroup leaders, and members of the technical staff. Their remuneration depends only on their competence and total experience.

Type of Company, Research Program, and Creativity

When a company is large enough and diversified enough it can indulge in fundamental research because, regardless of what discoveries are made, new knowledge can be applied to specific product development in some one of its many departments. Research of this sort is necessarily less susceptible to close management by the business managers of the company than is development research.

On the other hand, medium sized, commodity-organized companies must usually make their principal effort in applied and product-development research. Consequently, business management of the company can take a much closer interest in research and is able to point out specific areas for research to a greater extent

than in the larger companies just described. The smaller company's effort must include product development, advertising consultation, and applications research, and sometimes basic research.

Some companies have made the change in their organization from a broad lateral one to a commodity-line organization, in which the manager of each commodity is responsible for all the research, development, and production of his particular area. At first, this change often results in a decrease in the number of patent applications, but the curve then often reverses itself as the staff become more and more adjusted to the new environment. Companies have made this change because, formerly, developments which got into production were those which had the most articulate sponsors; equally good developments were being slighted when they were not in the hands of individuals who had close contact with the development people.

In summary, it is the usual experience that whenever a laboratory organization changes from a centralized one to a decentralized one, or vice versa, or from a broad lateral organization to a commodity-line organization, or from an authoritarian atmosphere to a permissive atmosphere, the creative activity of the organization drops off for a time. When the members have adjusted to the new environment, the creativity usually swings upward again. A certain amount of organization is absolutely necessary in order to facilitate periodical appraisals of individual researchers so that they may know just where they stand and how they are performing their jobs. However, the minimum organization possible is the best organization, and people then will feel free to go across department lines and unearth problems and make suggestions in any area in which they have an idea.

Creativity of Committees

Some of the conferees felt that a central research committee is not a bad idea for a large organization; even if they come up with only five or six ideas per year, this is all on the plus side. Another

participant said their suggestion committe gets 65% of its ideas from research people, 35% from people outside research. All ideas are given a literature search. The committee also has a small group (three chemists) who can work on the idea in the laboratory to determine its feasibility. The important thing is that every idea is given a review by more than one person so that prejudice cannot enter the picture. It was stressed that it is extremely important in the evaluation of ideas to make certain the originator is informed of the result of the evaluation and to make sure he agrees with the committee's decision to either drop or follow up the idea.

Psychological Factors Affecting Creativity

The Director's Role in Increasing Creativity

One of the attendees described the *modus operandi* of his most successful research director. This man attends a wide variety of professional meetings, visits his competitors' laboratories, explores all divisions of his own company, and gradually forms a picture of newly developing areas that he feels will be of greatest importance in the future. He then gradually evolves specific areas in which he feels his people can do productive research, and, by numerous informal conversations with his co-workers, gradually sells the idea of exploratory work in these fields to the research men at the bench. Eventually, he finds the people in his group are getting into research in these new areas. This man is a relatively poor administrator, because he attacks personal problems in the same way he does the scientific ones without taking into consideration the human values involved; however, since a good research director must be primarily creative and secondarily good in human relations, research management tries to remove all possible administrative burdens from the director. Administrative assistants take care of the problems of expense accounts, requisitions, administration of government contracts, travel vouchers, budget affairs, and other matters.

Another conferee described the evolution of the research director as proceeding from a superb scientist who gradually, over a period of years, gets involved in trying to solve administrative problems simply for the purpose of maintaining a good atmosphere for his creative work. In this way, he acquires a good deal of administrative know-how without deliberately trying to do so.

Some people felt that a research director must lead his group, others that he should manage the group, and others that he should just get out of their way and let his competent scientists go ahead. Involved here is the problem of whether or not it is good for a director to compete with his men in inventiveness, or whether he should stop working creatively and let his people make their own contributions.

Admittedly, one of the greatest problems in promoting a person to a first-line supervisory job is to get him to accept the role of leader. All too frequently, the man has a tendency to just go along with his subordinates' suggestions, trying to be a collaborator or a good fellow, without exercising positive leadership. It is acknowledged that the group leader should exert an encouraging influence, and that positive encouragement has to be based upon respect by his people for the man's professional accomplishments.

Laboratory's Tradition or Reputation for Success

The group pointed out that the traditional record of creative production which some laboratories enjoy is a powerful factor in continuing creativity. This shows up very markedly in the ease with which these laboratories can recruit new graduates directly from school.

Permissive vs. Authoritarian Atmospheres

The effect of the laboratory's organizational atmosphere on its creativity has been discussed earlier under freedom of action as an environmental policy and under organizational factors affecting

creativity. Also, of course, it is a psychological factor and could well be discussed at this point. Many of the people in the meetings felt this was such an important subject it could well be made the topic for a later study group meeting. Others felt it was simply a matter of traditional background of the people involved and a part of national character. In other words, countries in which the people have traditionally accepted authority will have industrial research laboratories conducted along authoritarian lines, whereas countries of a democratic nature will have laboratories with a highly permissive atmosphere for their work.

Frequency of Reports

Many people at the meetings felt that the requirements for very frequent reports could definitely be overdone. It is quite possible to overcommunicate, and scientists sometimes find themselves spending an inordinate amount of time writing reports to too many different people and departments. The representative of one highly successful laboratory said that recently his firm changed from a system of monthly reports to quarterly reports of the research results of the scientists. This laboratory averages about one technical paper per year per technical man. This is considered to be a very high average for an industrial research laboratory.

Desire to Contribute to Betterment of Mankind

Some people are stimulated to enter the physical sciences simply because they see this as a good route to making a significant contribution to the advancement of civilization and betterment of mankind's life on earth. Others have a deep-seated sense of obligation to make use of their talents to this end. It is undoubtedly true that most good scientists feel both of these impulses, to some extent, whether they are the principal motivating influence or not.

Other Factors Affecting Creativity

Although the conferees acknowledged this is a somewhat negative approach to the psychological factors affecting creativity, they decided to list a number of the definite impediments to creativity. Most of these have been pointed out in other sections.

As far as laboratories are concerned, they mentioned that a minimum noise level is very important; enclosed offices in the laboratory are helpful to get a man out of the stream of traffic. Talking noise is much more distracting than steady machine noises. Air conditioning is very important during summer months and is helpful in recruiting new people; both creativity and productivity decline sharply during the summer months in a laboratory which is not air-conditioned. Crowding in laboratories is very distracting. Safety restrictions which prevent lone workers from coming in at "off" hours definitely hinder creativity.

The necessity for carrying out administrative duties is admittedly a stifling influence on the creative worker, as is all routine paper work and red tape. These items have already been discussed.

It was again emphasized that uncertainties in an organization, especially those arising when there is a hint that a reorganization is in the making, often lead to a sharp decrease in productive activity. Several people commented that regardless of whether a laboratory was being centralized or decentralized, it is a great upsetting influence on the individual research workers. After a time, they settle down and become as productive as formerly. It is a striking thing that people whose whole professional goal is to bring about revolutionary new developments are so upset when their own lives are disrupted and reorganized.

Appraisal of the Value of These Study Groups

The consensus of the people attending these small, two-day study groups was that they were of great value in clarifying very pertinent problems. Several expressed a desire to return home and

discuss with their most creative people the opinions and philosophies brought out in the present discussions. It was felt that such feedback should be beneficial, although probably no obvious results could be expected in less than one year. The conferees were unanimous in saying that they would advocate their company should send other people to similar discussion groups if they are held next year.

Several remarked they would like to hear more case histories of experiences along the lines heard during these meetings. It was pointed out that the 1960 Seminar on Management of Industrial Research sponsored by the Industrial Research Institute at the Harvard Graduate School of Business Administration would have a number of very good case histories, and the course will be based in large part upon this approach.

It was also pointed out that one of the greatest difficulties in conducting these meetings is to conduct them in such manner that the conferees do not lose too much time in developing rather fundamental concepts on which everyone agrees. No one felt that the subject matter discussed by this study group should have been restricted to a smaller segment.

On the question of whether these conferences should be conducted with mixed levels of representatives at the same meeting, it was agreed we should not have two different title levels from the same company at the same meeting. It was felt that a meeting with representatives from lower echelons of research might result in some new viewpoints.